# Coupled Ocean-Atmosphere Modeling of the Coastal Zone


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## LONG-TERM GOAL

The long-range goal of this project is to improve our ability to understand and predict environmental conditions in the coastal zone.

## OBJECTIVES

The primary scientific objectives of the proposed research are to use a coupled atmosphere--ocean model to investigate and quantify the interaction between the oceanic and atmospheric boundary layers and its effect on environmental conditions in the coastal zone. The main focus will be on boundary layer interactions under coastal upwelling conditions, in which cold, upwelled ocean surface water induces the development of stable internal boundary layers in the atmosphere and thereby reduces low-level winds and surface stress.

## APPROACH

The approach used in this project is to combine numerical model results with in-situ and remote-sensing observations to understand and quantify physical processes in the coastal, coupled atmosphere-ocean and test their representation in mesoscale atmospheric models.

## WORK COMPLETED

Efforts this year have focused on expanding the coupled COAMPS/ROMS model by improving the model lateral boundary conditions and adding atmospheric moist processes. Improved boundary conditions have allowed for much longer simulation times (14 days) and allowed for the reintroduction of moist cloud processes. We have also initiated simulations of coastal stratus systems using large-eddy simulation (LES) and will begin contrasting the mesoscale cloud predictions with the more detailed LES results.

# Report Documentation Page

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14. ABSTRACT
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## RESULTS

### Mesoscale Modeling

We consider two coastline scenarios in examining the importance of coastal terrain on winds and upwelling as shown in Figure 1, expanding on the one-dimensional case presented in Perlin, et al. 2007. In both cases, the major response of the flow is similar to past studies of flow around points (e.g. Burk et al. 1999) showing a region of increased winds downstream from the point or bend in the coast, with a fanning of the wind vectors.

(a) (b)

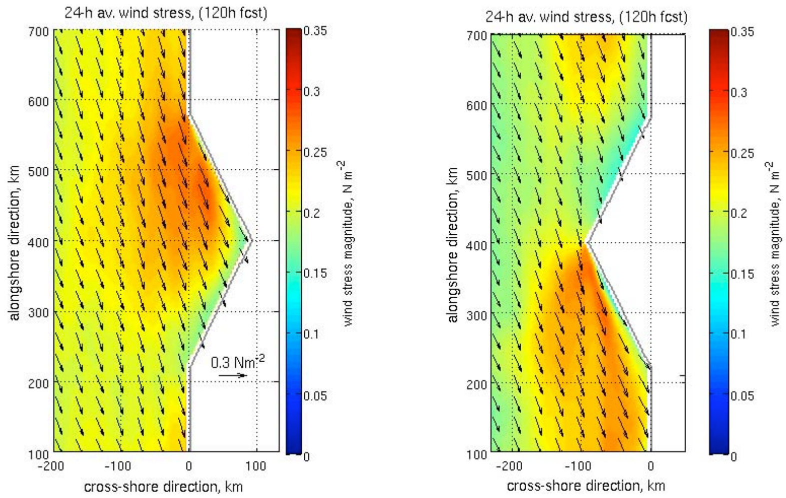


***Figure 1. Wind stress (shaded) and wind vectors averaged over 24 hours for a (a) bay, no coupling, and (b) point no coupling. Simulation is 5 days in duration.***

Simulations with diurnal heating suggest that there is a strong response in the strength of the offshore flow for the point scenario, especially in the region of the expansion fan downstream from the point (Figure 2 and 3). Winds in this region are a minimum just after sunrise and accelerate from late morning until early evening, with wind stresss doubling in magnitude over this time period. Upwind from the point, diurnal effects are much smaller with only slight increase during the daytime hours. Observations of orographically intensified expansion-fan flow along the U.S. west coast have also shown a strong diurnal cycle (Samelson and Lentz, 1994), which will be compared to the coupled simulations.

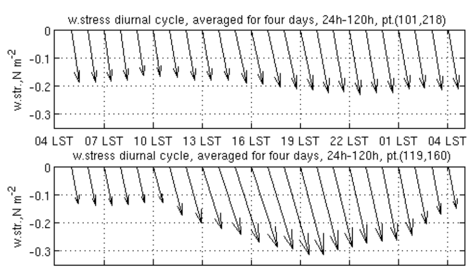


***Figure 2. Wind stress at x = 101 km, y = 218 km (top) and x = 119 km, y = 160 km , as a function of time. Values are averaged over a 4 days.***

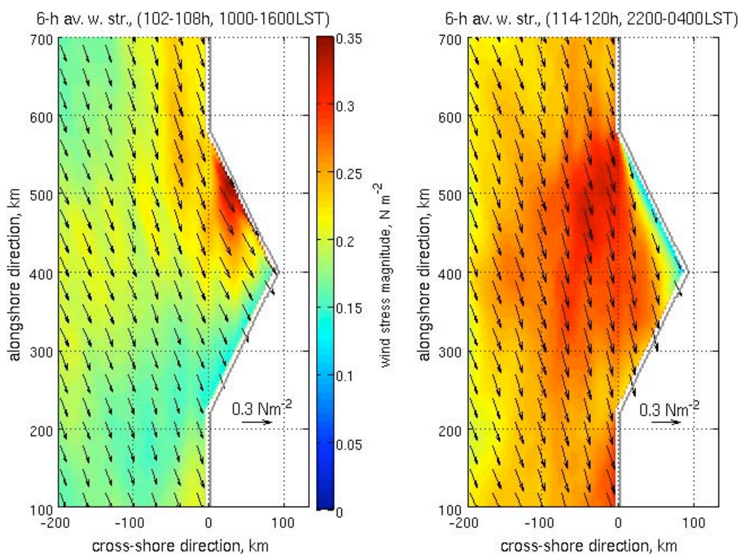


***Figure 3. Wind stress averaged over 6 hour period representing (a) daytime and (b) nighttime for uncoupled case.***

Simulations are currently underway to examine the longer term effects of coupling after 5-10 days of wind forcing. We are also conducting experiments with moist processes to determine how coastal circulations affect cloud formation and evolution.

**Stratocumulus Simulations**

Initial simulations of stratus clouds using LES have focused on the cloud formation process. Our goal in these experiments is to better understand how stratocumulus clouds form over cold water as commonly observed in coastal regions. Stratus clouds are typically forced by radiative cooling at the cloud top, which destabilizes the local atmosphere and generates vertical motion. Subsidence prevents stratus clouds from expanding vertically, and if strong enough, can prevent cloud formation. Experiments have focused on formation of stratocumulus as the marine boundary layer deepens. We start the simulation with a boundary layer structure that is subsaturated, with a sea-surface temperature that is slightly larger than the boundary layer temperature. Clouds that form in this environment consist of a combination of stratus clouds and small cumulus towers as shown in Figure 4. As the simulation continues, clouds thicken and coverage increases as the layer where the air is saturated increases.

Overall, the model produces a reasonable representation of stratus clouds for relatively deep boundary layers where the vertical resolution is high. High vertical resolution is a critical factor in accurate stratus simulation because of the importance of cloud top entrainment in dissipating clouds. If resolution is too low, then entrainment rates are artificially increased through numerical smoothing. Consequently, coarse resolution can lead to broken cloud coverage and eventual dissipation of clouds as dry air from above the boundary layer is mixed downward. This effect is important for mesoscale simulations where vertical grid spacing is often too large to adequately resolve thin stratus cloud layers.

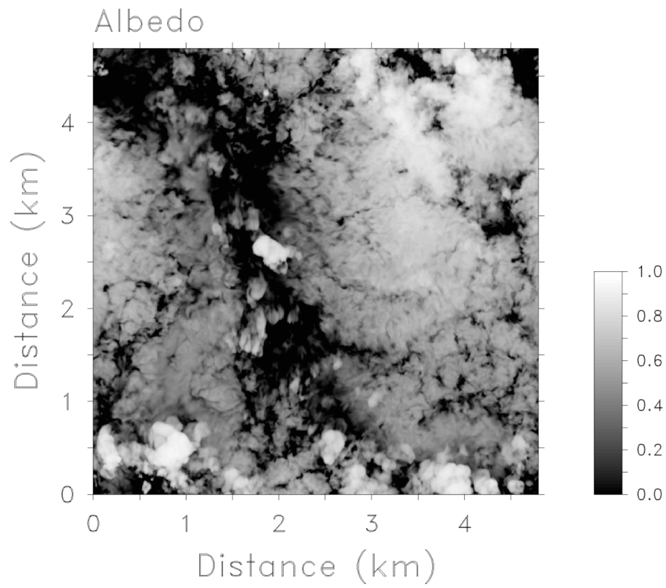


***Figure 4. Cloud albedo for stratocumulus simulation after 4 hours.***

In cases where the boundary layer is very shallow or water temperature is falling, as in upwelling regions, fog formation is possible. We plan to use the LES model to better understand how fog formation is affected by the balance between radiative cooling, evaporation of cloud water, and entrainment of dry air. As an example of this balance we present a budget from a deeper stratocumulus boundary layer in Figure 5. Clouds in this system are modified by both turbulence processes (entrainment and evaporative cooling) as well as radiation at the cloud top near 2000 m.

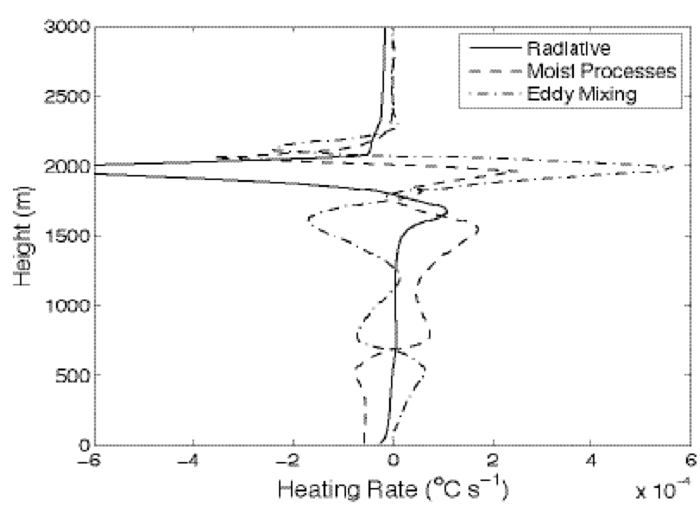


***Figure 5. Simulated average rates of heating forced by radiative cooling, cloud droplet and precipitation evaporation and condensation, and eddy mixing for a cloud topped boundary layer.***

## RELATED PROJECTS

Coupling techniques developed as part of this research are currently being used as part of the NOPP Community Sediment Transport Model development.

## REFERENCES

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## PUBLICATIONS

Skyllingstad, E.D., and J. B. Edson, 2008: Large-eddy simulation of moist convection during a cold air outbreak over the Gulf Stream. J. Atmos. Sci., accepted for publication.